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SSIC NO. 5090.3

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Ser 1831.4/L6307
19 Jul 1996

From: Commanding Officer, Engineering Field Activity, West, Naval Facilities Engineering Command
To: Distribution

Subj: HYDROGEOLOGIC INVESTIGATION FOR FUNNEL AND GATE DEMONSTRATION, SITE 1, NAS ALAMEDA

Encl: (1) Work Plan for Hydrogeologic Investigation, Site 1, NAS Alameda, prepared by Einarson, Fowler and Watson, dtd 16 July 1996

1. Einarson, Fowler & Watson (EFW) has submitted enclosure (1), a draft of the Work Plan for the Hydrogeologic Investigation at IR Site 1 (1943-1956 Disposal Area), NAS Alameda. The proposed investigation will complete the site assessment necessary to select a location for the Funnel and Gate technology demonstration by University of Waterloo. On-site mobilization for the investigation is scheduled for 22 July.

2. EFW is revising the Health and Safety Plan based on comments from the EFA West Industrial Hygienist and Safety Specialist.

3. The work plan is being provided to the regulatory agencies for information purposes. Although a formal review is not required, regulatory concerns should be forwarded to me.

3. If you have any questions or comments, call me at 415-244-2539 or fax at 415-244-2654.

Original signed by: CG

for KEN SPIELMAN
By direction of
the Commanding Officer

Distribution:
NAS Alameda (Attn: Mr. Steve Edde)
California Department of Toxic Substances Control (Attn: Mr. Tom Lanphar)
California Regional Water Quality Control Board (Attn: Ms. Gina Kathuria)
U.S. Environmental Protection Agency (Attn: Dr. Barbara Smith)

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EINARSON
FOWLER & WATSON
Consultants In Environmental Hydrogeology & Engineering

July 16, 1996
Project No. ANA101

Mr. Ken Spielman
Engineering Field Activity, West
Naval Facilities Engineering Command
900 Commodore Dr., Code 1831.4
San Bruno, CA 94066-5006

Re: Hydrogeologic Investigation, Site 1, Alameda Naval Air Station, Alameda, California

Dear Mr. Spielman:

On behalf of the Department of Earth Sciences, University of Waterloo (UW), Einarson, Fowler & Watson (EFW) is presenting this draft workplan for activities related to the site hydrogeologic investigation for Site 1, Alameda Naval Air Station, Alameda, California (Figures 1 and 2).

INVESTIGATION TASKS

The following scope of work is for the site investigation only and is designed to provide additional hydrogeologic characterization of the site to help identify an area in which a pilot-scale remedial technology demonstration could be undertaken. The scope has been broken down into the following tasks, which are described below:

- Geologic Profiling
- Monitoring Well Installation
- Groundwater Geochemical Profiling
- Hydraulic Testing

This work will be conducted by EFW, a Bay Area consulting firm particularly familiar with the coring and profiling systems and procedures. A UW scientist will be on-site during most of this activity, to provide technical direction and to coordinate with Alameda NAS staff as required.

Enclosure (1)

2650 East Bayshore Road • Palo Alto, California 94303 • Telephone 415.843.3828 • FAX 415.843.3815

The proposed program must be flexible. That is, the location of coring or groundwater profiling will be based, in part, on information being collected in the program. All investigation activities will occur within the approximate study area shown on the attached map, but the specific points shown may be changed as information becomes available.

All results will be reported to Mr. Ken Spielman, EFA West, and others as required.

Geologic Profiling

In order to further define the site hydrogeology, EFW will drill and continuously log approximately three borings within a subsection of Site 1. Proposed boring locations are shown on Figure 2; exact boring locations will be determined in the field based on information obtained in the field. Borings will be drilled and continuously cored by Precision Sampling, Inc. (PSI) of San Rafael, California, using direct-push methods (i.e., Enviro-Core®). Appendix A presents a summary of the Enviro-Core® sampling system.

If heaving sand conditions occur, PSI will use a piston sampler (Figure 3). With a piston sampler the opening of the sample barrel is sealed with an air- and water-tight piston. The barrel is simultaneously pushed, driven, or vibrated into the ground. When the sampler has been pushed to the desired sampling depth, the piston is unlocked, and subsequent pushing or driving forces the soil inside the sampler as the piston retracts. The process is repeated until the desired coring depth has been obtained.

In general, borings will be advanced to the base of the shallow groundwater zone, approximately 22 feet below ground surface (bgs). Soil core will be logged by an EFW geologist using the Unified Soil Classification System (USCS). Soil samples will be collected and analyzed for volatile organic contaminants by a UW scientist. Soil core will be screened for radio active decay (RAD) prior to sample collection or logging. Soil with unacceptable levels of RAD will not be logged or sampled.

Monitoring Well Installation

Each boring will be converted to a fully-screened monitoring well (approximately 7 to 22 feet bgs) following completion of soil sampling and logging. Well construction will consist of a schedule 40, 1.25-inch-diameter Polyvinyl-Chloride (PVC) pipe with approximately 15 feet of slotted PVC screen. Bentonite pellets and Portland Cement will be used for an annular seal.

Groundwater Geochemical Profiling

In order to further evaluate the distribution of organic contaminants in the shallow aquifer, a Waterloo Drive-Point Profiler will be used to collect 3 to 5 depth-discrete water samples at approximately 12 locations (Figure 2). The Waterloo Drive-Point Profiler is a well point with screened ports located at the tip of the tool (Figure 4). The ports are connected to an internal tube that extends up through the direct push rods to ground surface. During sampling, the profiler is advanced and deionized water is simultaneously pumped out the sampling ports to prevent them from clogging. Once a desired depth is reached, the flow of the pump is reversed and groundwater from the aquifer is extracted. Purging is complete when the electrical conductivity of the extracted groundwater is stabilized. Once the sample is collected, the profiler is again advanced and simultaneously purged with deionized water until the next sampling depth is reached. A paper detailing the use of the Waterloo Drive-Point Profiler to profile volatile organic compound (VOC) plumes in groundwater is included in Appendix B.

Hydraulic Testing

EFW will conduct slug tests in the newly-installed monitoring wells. A slug test is commonly performed by inserting into and removing from the well a cylindrical object, or "slug". The hydraulic conductivity of the water-bearing zone is calculated based on well geometry and the relationship between the change in water level and elapsed time since the insertion or removal of the slug. Changes in water level will be continuously logged using a pressure transducer, data logger, and laptop computer.

HEALTH AND SAFETY

A site health and safety plan for this hydrogeologic investigation is presented in Appendix C. This health and safety plan addresses expected hazards, monitoring, and proposed mitigation for potential exposure to low-level VOCs and low-level radioactivity.

WASTE DISPOSAL

All groundwater samples, purge water, and soil cores will be screened in the field for levels of VOCs and radioactivity using hand-held field instrumentation. Purge water and soil cuttings not collected for sampling will be placed in a container suitable for the type of waste generated, and properly disposed of consistent with the type of waste generated. Radioactive soil will be segregated and placed in 10-gallon metal buckets in a secured low level RAD waste yard, located on site. Because of the geological and geochemical profiling methods used during this investigation, only a small volume of waste soil is expected to be generated (less than 1 to 3 cubic feet).

SCHEDULE

We intend to begin field work the week of July 22, 1996. It is estimated that field work will last approximately five days.

If you have any questions about this workplan or the site health and safety plan, please call us at (415) 843-3828.

Sincerely,
Einarson, Fowler & Watson

for

Murray D. Einarson, C.H.
Principal Hydrogeologist

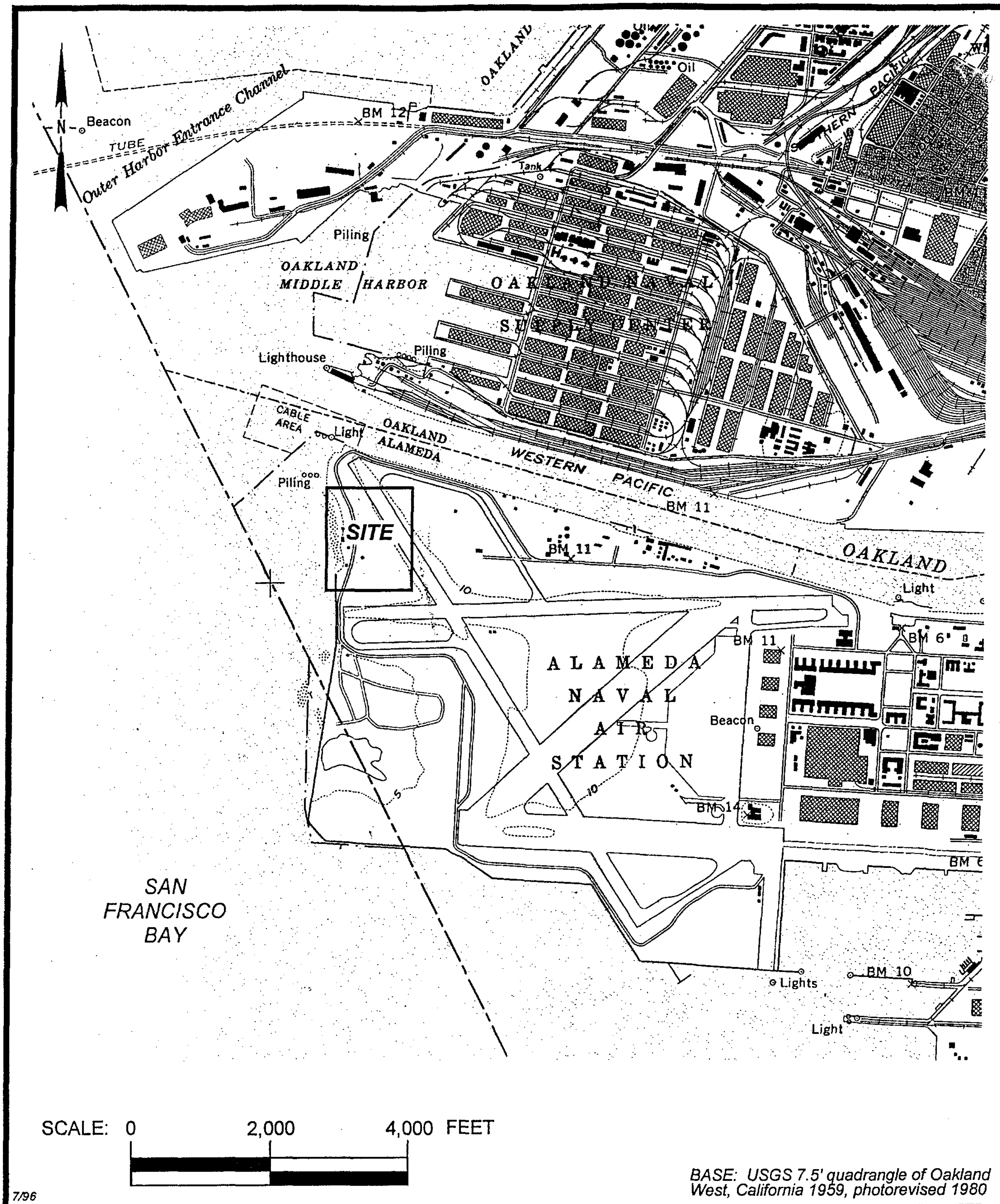
Figures

Figure 1 - Site Location Map
Figure 2 - Area 1 Map
Figure 3 - Piston Sampler
Figure 4 - Waterloo Drive Point Profiler

Appendices

Appendix A - Enviro-Core®-A New Direct-Push Technology for Collecting Continuous Soil Cores
Appendix B - The Waterloo Drive-Point Profiler, Detailed Profiling of VOC Plumes in Groundwater
Appendix C - Site Health and Safety Plan

cc: Mary Morkin, University of Waterloo



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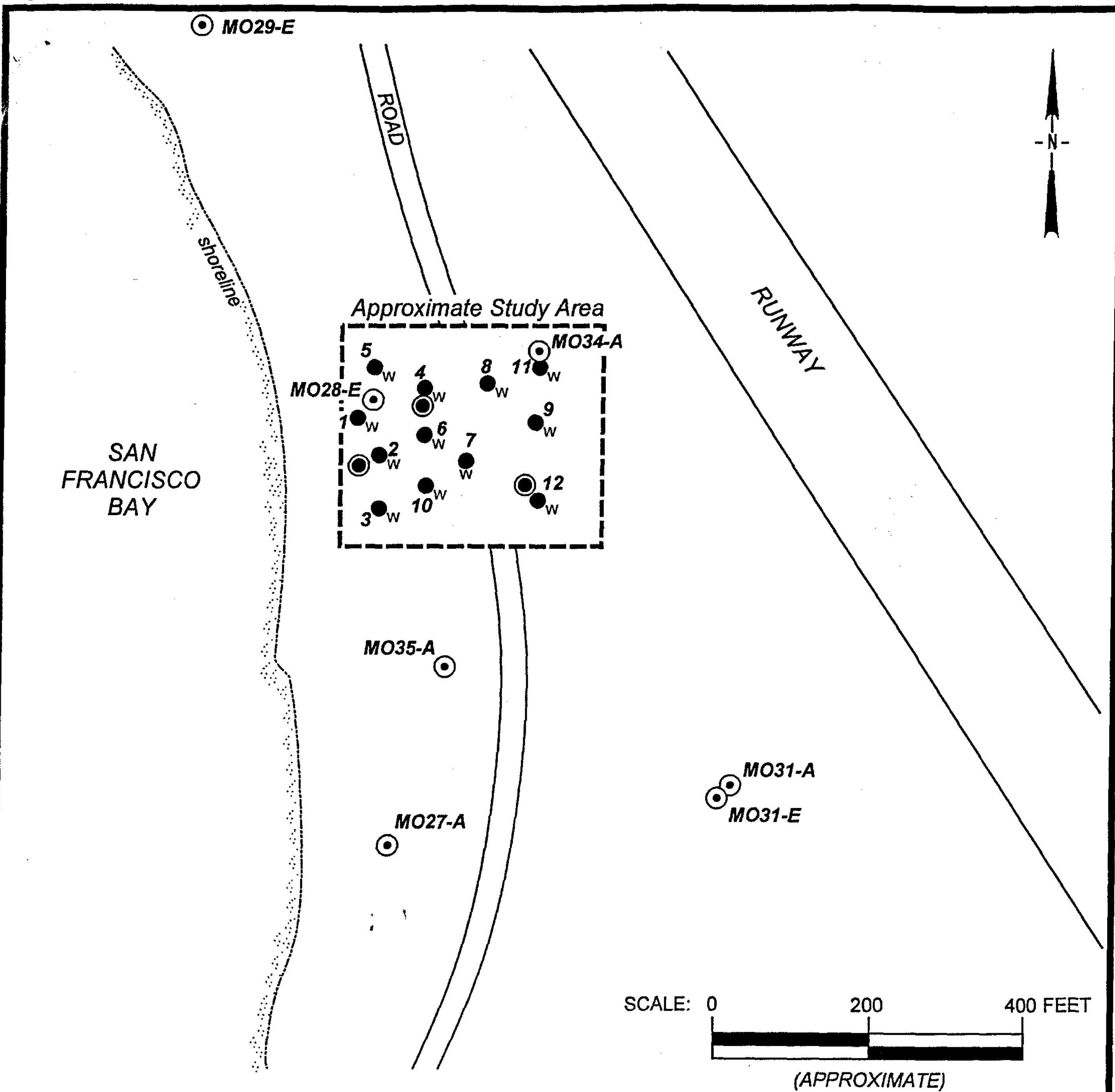
HYDROGEOLOGIC INVESTIGATION
ALAMEDA NAVAL AIR STATION
ALAMEDA, CALIFORNIA

SITE LOCATION MAP

FIGURE 1

PROJECT NO. ANA101



EXPLANATION

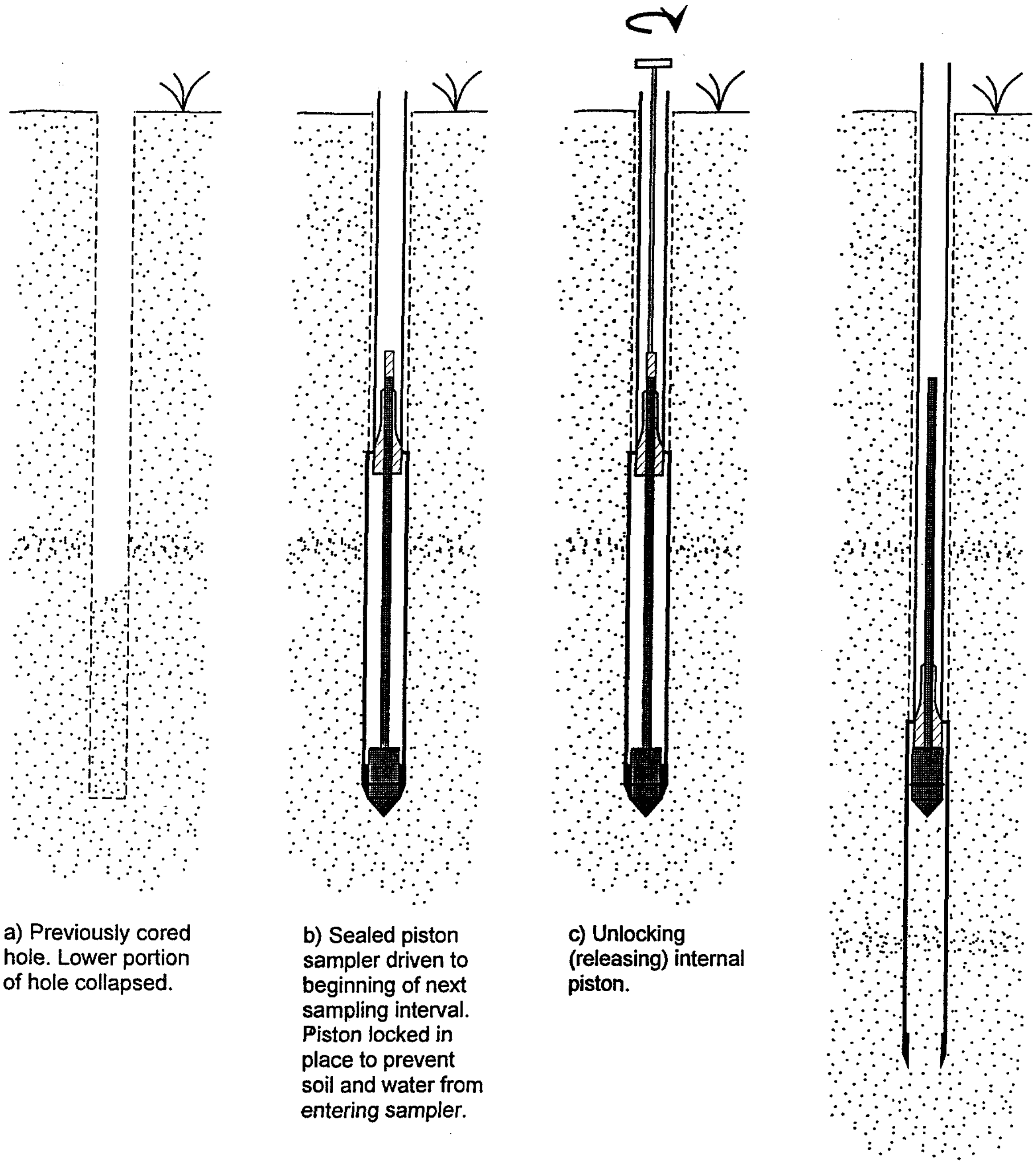
Proposed Soil Core and Well Location

W Proposed Groundwater Profiling Location

NOTE: Actual locations of data points will be determined in the field based on findings as the field work progresses.

7/96

EINARSON FOWLER & WATSON	HYDROGEOLOGIC INVESTIGATION ALAMEDA NAVAL AIR STATION ALAMEDA, CALIFORNIA	FIGURE 2
	AREA 1 MAP	PROJECT NO. ANA101



a) Previously cored hole. Lower portion of hole collapsed.

b) Sealed piston sampler driven to beginning of next sampling interval. Piston locked in place to prevent soil and water from entering sampler.

c) Unlocking (releasing) internal piston.

d) Sampler driven to collect next soil core. Piston remains stationary while soil enters sample barrel. Soil core retrieved by removing entire assembly from hole.

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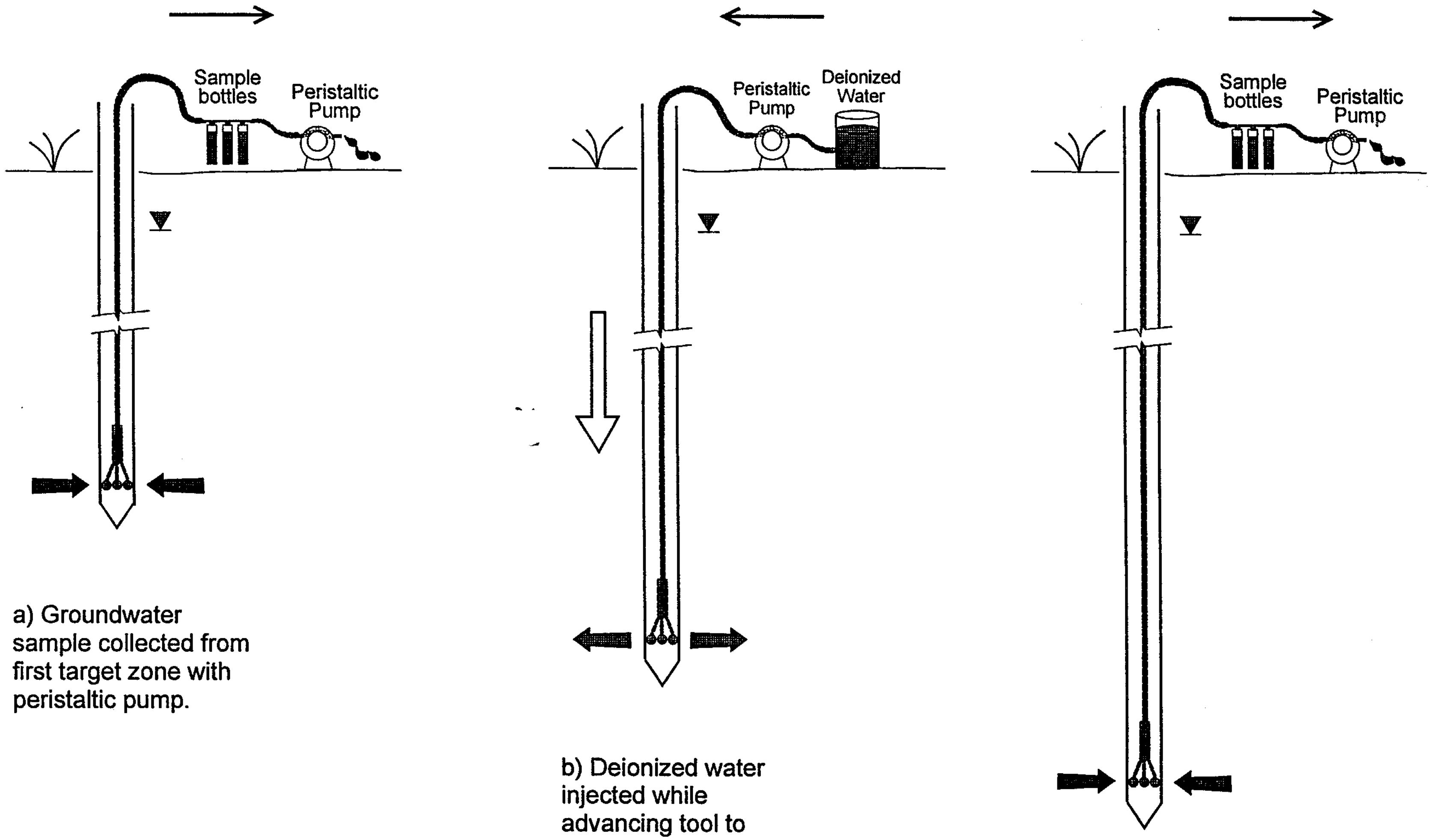
HYDROGEOLOGIC INVESTIGATION
ALAMEDA NAVAL AIR STATION
ALAMEDA, CALIFORNIA

PISTON SAMPLER

FIGURE 3

PROJECT NO. ANA101



a) Groundwater sample collected from first target zone with peristaltic pump.

b) Deionized water injected while advancing tool to prevent sampling ports from becoming plugged.

c) Groundwater sample collected from second target zone with peristaltic pump.

Source: Pitkin, 1994

EINARSON FOWLER & WATSON	HYDROGEOLOGIC INVESTIGATION ALAMEDA NAVAL AIR STATION ALAMEDA, CALIFORNIA	FIGURE 4
	WATERLOO DRIVE POINT PROFILER	PROJECT NO. ANA101

Appendix A

Enviro-Core®-A New Direct-Push Technology
for Collecting Continuous Soil Cores

Presented at the 9th National Outdoor Action Conference, *Las Vegas, Nevada, May 1995*

Enviro-Core® — A New Direct-Push Technology for Collecting Continuous Soil Cores

Murray D. Einarson, C.E.G.
Einarson Geoscience, Inc.
Palo Alto, California

Abstract

Enviro-Core® is a new direct-push system for quickly collecting continuous soil cores in unconsolidated sediments. Unlike conventional drilling techniques, no drill cuttings are generated with the Enviro-Core system, eliminating the expense of waste soil disposal or treatment. The Enviro-Core system consists of 2.4-inch-diameter drive casing and an inner sample barrel that are simultaneously pushed, driven, or vibrated into the ground.

Continuous soil cores are collected in stainless steel liners inside the inner sample barrel. After being advanced three feet, the inner sample barrel is retrieved, while the drive casing is left in place to prevent the borehole from collapsing. The drive casing ensures that subsequent soil samples are collected from the targeted interval, rather than potentially-contaminated slough from higher up in the borehole. After retrieving the inner sample barrel, the sample liners are removed for chemical analysis or lithologic identification. A new three-foot inner barrel, fitted with stainless steel liners, is quickly lowered to the bottom of the borehole. An additional three-foot section of Enviro-Core drive casing is attached at the surface, and the process is repeated until the desired depth is reached.

The Enviro-Core system is also used to collect soil gas and grab groundwater samples. Once the target zone has been penetrated, the drive casing can be pulled back to expose the desired interval of the borehole wall, and soil vapor samples are extracted with a vacuum pump. Similarly, once a water-bearing zone has been penetrated, the drive casing can be withdrawn slightly, allowing groundwater to flow into the casing. Groundwater samples are then collected with a peristaltic pump, check-valve tubing pump, or small-diameter bailer.

The use of small-diameter drive casing facilitates in situ hydraulic testing, geophysical logging, and installation of small-diameter piezometers, monitoring points, air sparging points, and SVE points. The Enviro-Core drive casing may also provide a way to selectively fracture contaminated fine-grained strata in order to improve the effectiveness of many in situ remediation techniques.

The Enviro-Core system was used to characterize a LUFT site in Redwood City, California. Use of the Enviro-Core system, in conjunction with a mobile lab and on-site data evaluation, resulted in a thorough characterization of the site geology, hydrogeology, and nature and extent of contamination in just two days.

Introduction

In recent years, the environmental industry has witnessed explosive growth in the development and use of innovative technologies for site characterization. The need for new tools for site characterization became apparent in the mid 1980's. Up until then, environmental professionals relied on technology borrowed from other industries, in particular the geotechnical and water well drilling industries. When the costs of conventional investigations and long-term groundwater monitoring were totaled, it became clear that the environmental industry needed better ways to characterize contaminated sites more quickly and more thoroughly.

The environmental industry responded, and new technologies for site characterization were developed. Soil gas sampling using small-diameter probes (e.g., Geoprobe®-type sampling) and on-site chemical analysis of soil gas samples with mobile labs helped to quickly define the nature and extent of adsorbed and dissolved contaminants. The Hydropunch® and BAT® Enviroprobe, driven probes used to collect groundwater samples, quickly became popular tools for plume delineation. Cone penetrometer testing (CPT), utilized extensively in the geotechnical industry, became a valuable tool to quickly define the stratigraphy of unconsolidated sediments during environmental investigations. The late 1980's and early 1990's witnessed the marriage of CPT for lithologic control, and BAT or Hydropunch systems for collecting groundwater samples. Most recently, these new methods are being referred to collectively as "Direct-Push" (DP) technologies, since they are typically pushed or driven into the ground.

While these new DP methods are welcome additions to a field geologist's "site characterization tool kit", none have been very successful at quickly collecting continuous soil cores, a vital component of any subsurface investigation. Continuous soil coring is often the only way to identify thin permeable layers (e.g., sand partings), artificial fill, zones of discolored soil, free product, and secondary pedologic features (e.g., root holes and desiccation cracks). These elusive features commonly control the movement of contaminants in the subsurface, and the effectiveness of in situ remediation technologies such as soil vapor extraction (SVE) and air sparging.

In 1990, Precision Sampling, Inc., of San Rafael, California, miniaturized components of large, conventional drilling rigs (i.e., drive casing and wireline core barrels), and developed a way to quickly advance the small-diameter sampling tools into unconsolidated sediments without rotating the drill string. Precision's Enviro-Core system (patent pending), cases the borehole as it is deepened, and allows rapid collection of continuous soil cores, soil gas samples, and groundwater samples. Like other DP systems, no drill cuttings are generated, saving the cost of disposing of the contaminated drill cuttings.

The Enviro-Core system is advanced using small, portable, vibratory rigs, although the system could be adapted for use by CPT rigs and conventional drilling rigs. The Enviro-Core system is currently capable of sampling to depths of 50 feet with nearly 100% sample recovery and can collect up to 150 feet of continuous soil cores per day.

Enviro-Core® Sampling System

The Enviro-Core system consists of small-diameter drive casing and an inner sample barrel that are simultaneously pushed, pounded, or vibrated into the ground. Continuous soil cores are collected in stainless steel liners inside the inner barrel. After being advanced three feet, the inner barrel is retrieved, while the drive casing is left in place to prevent the borehole from collapsing. The drive casing ensures that subsequent soil samples are collected from the targeted interval, rather than potentially-contaminated slough from higher up in the borehole.

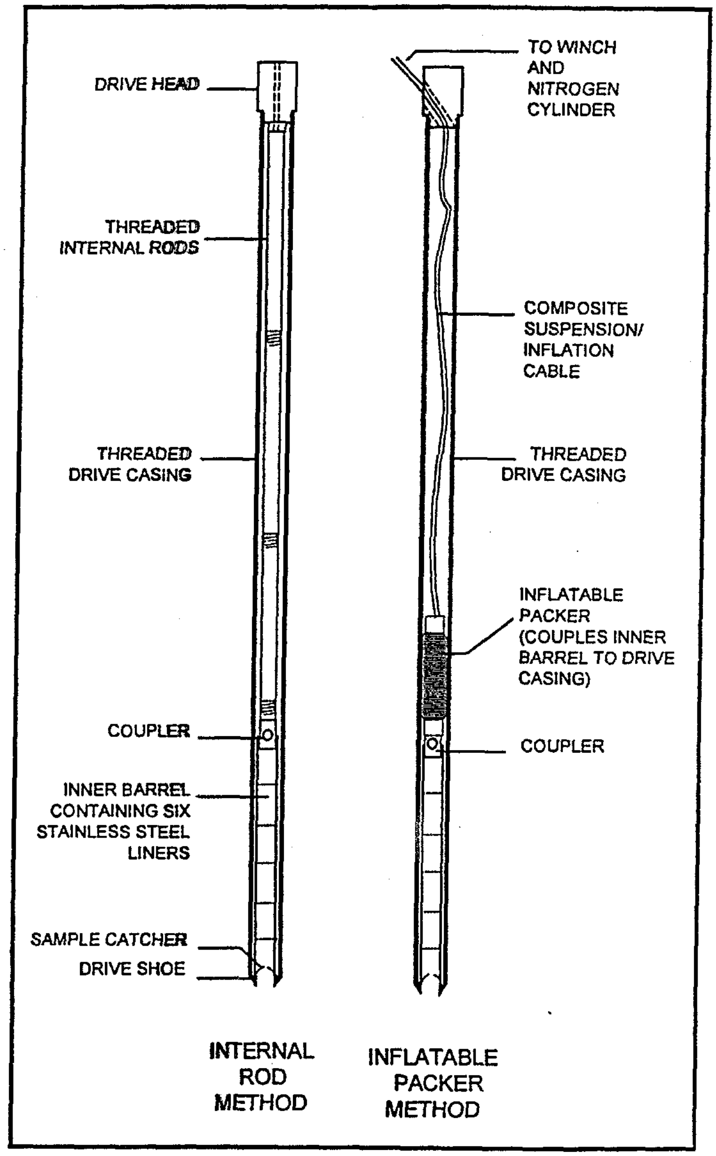


Figure 1. The Enviro-Core® System

The custom-made drive casing has an outer diameter (OD) of 2.4 inches and is machined into 3-foot-long, threaded sections. A heat-treated steel drive shoe is threaded onto the bottom piece of drive casing, and a steel drive head is threaded onto the top section of casing.

The inner barrel is made of a 3-foot-long section of 1.8 inch OD, thin-walled steel tubing. The inner barrel has an OD slightly smaller than the inside diameter (ID) of the drive casing, to allow it to be raised and lowered freely inside the drive casing. The bottom of the inner barrel rests on a shoulder cut into the drive shoe. The inner barrel contains six 1.7-inch-diameter by 6-inch-long stainless steel liners. A custom-made synthetic sample catcher is affixed to the bottom of the inner barrel to prevent loose sediments from falling out of the sample liners when the inner barrel is retrieved.

The inner barrel and drive casing are advanced into the ground simultaneously, requiring an effective means of coupling the inner barrel with the outer drive casing. This is achieved in one of two ways. The first method, referred to as the internal rod method, uses internal steel rods to keep the inner sample barrel seated against the drive shoe (Figure 1). The internal rods (three-foot sections of 1.38-inch-diameter steel EW sampling rods) serve several purposes. First, they are used to lower the empty inner barrel to the bottom of the steel-cased borehole. Then, the rods are placed in compression inside of the drive casing by attaching the drive head. This keeps the bottom of the inner barrel snug against the shoulder of the drive shoe, so that the soil moves easily into the sample liners as the drive casing is advanced. Finally, after the three foot run is complete and the sample liners are full of soil, the inner barrel (containing the stainless steel sample liners and soil) is retrieved by removing the internal rods.

While the internal rod method works well at shallow depths, recent improvements in the methods used to advance the Enviro-Core system have resulted in greater depths being attained. This, in turn, required a faster way to withdraw the inner barrel from the drive casing. An inflatable packer, commonly used to seal boreholes during hydraulic testing, was modified to provide a means of connecting the inner barrel to the drive casing (Figure 1). With this method, the inner barrel is coupled to the inflatable packer. The packer/inner barrel assembly is quickly lowered to the bottom of the drive casing with a wireline. The shoulder in the drive shoe prevents the inner barrel from protruding beyond the bottom of the drive casing. The packer is then inflated with compressed nitrogen, rigidly coupling the inner barrel to the drive casing. The inner barrel and drive casing are then simultaneously advanced three feet, filling the sample liners inside of the inner barrel with soil. The packer is then deflated, and the inner barrel/packer assembly is quickly removed from the boring with a winch. The sampling sequence is shown in Figure 2.

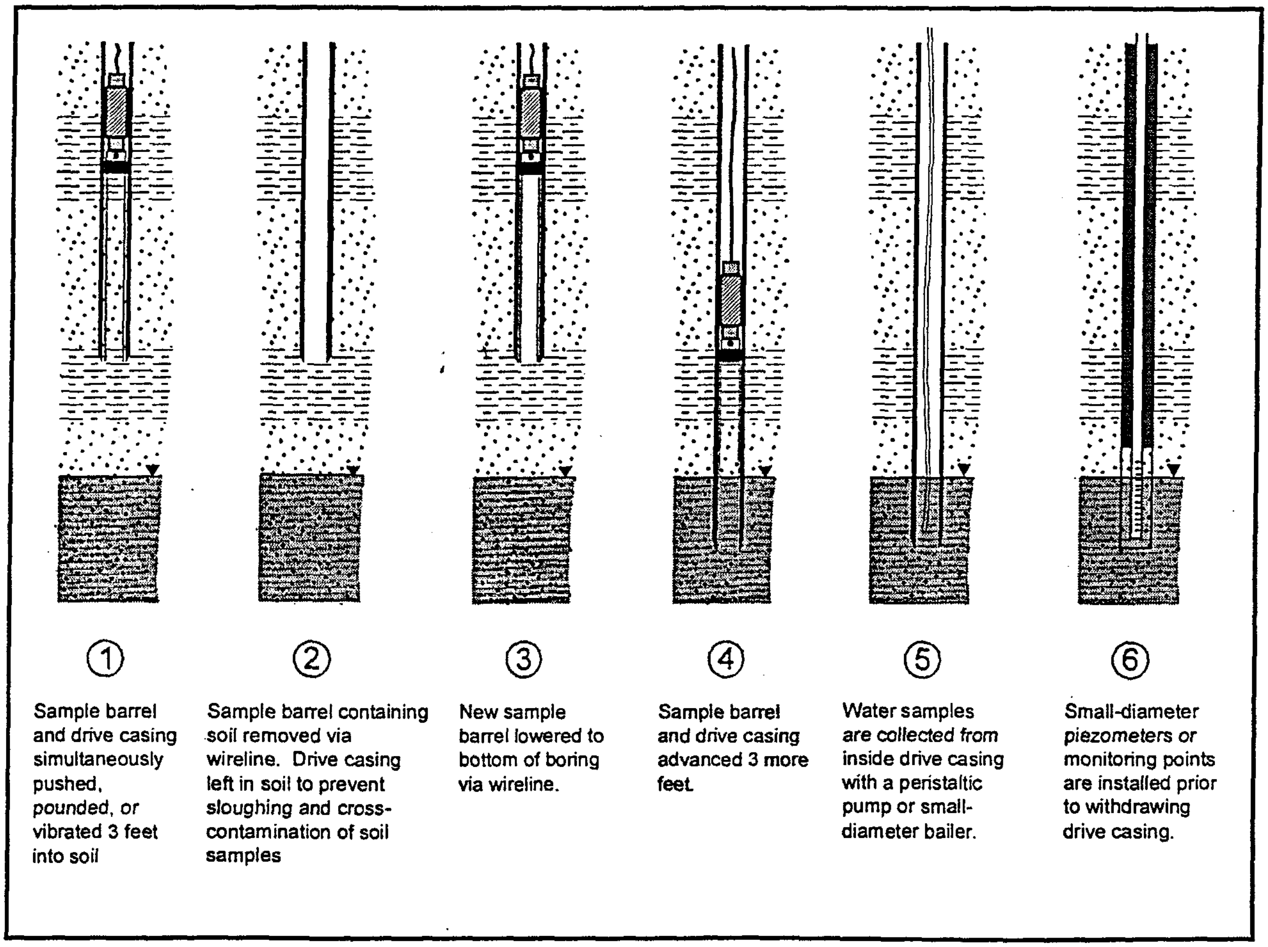


Figure 2. Sampling with the Enviro-Core® System

With both methods, after the inner barrel has been retrieved, the sample liners are removed for chemical analysis or lithologic identification. A new three-foot inner barrel, fitted with empty stainless steel liners, is quickly lowered to the bottom of the borehole. The inner barrel is then secured to the bottom of the drive casing (using either the internal rods or the inflatable packer). An additional three-foot section of drive casing is attached at the surface, followed by re-attachment of the drive head. The inner barrel and drive casing are simultaneously advanced three more feet, and then the inner barrel is again de-coupled and removed from the drive casing. This process is repeated until the desired depth is reached.

Methods for Advancing the Enviro-Core® System

Small, portable rigs push, pound, or vibrate the Enviro-Core system into the ground. The rigs are either stand-alone units, or can be mounted on Bobcat®-like construction vehicles (Figure 3) or in the back of utility trucks. To facilitate sampling beneath underground tanks and buildings, the rigs have been designed to advance the Enviro-Core system at angles up to 30 degrees from vertical.

As with most DP methods, the primary driving mechanism is the weight of the vehicle used to push the down-hole sampling equipment into the ground. The weight applied to the sampling equipment is commonly referred to as "reactive weight" or "crowd". The Enviro-Core system has been used with sampling rigs that transmit from 500 pounds to 3,500 pounds of reactive weight. As expected, the rates of penetration and maximum sampling depths are proportional to the reactive weight. Reactive weights greater than 3,500 pounds can be expected to further increase the rate of penetration and maximum sampling depth.

For maximum penetration, the Enviro-Core drive casing is usually pounded with a hydraulic hammer or vibrated with high-frequency industrial vibrators while the reactive weight is applied. The hydraulic hammer delivers 350 foot-pounds of impact force, compared to 135 foot-pounds delivered by most Geoprobe rigs. An anvil on the bottom of the hydraulic hammer transmits the striking force to the Enviro-Core drive head. The hydraulic hammer slides out of the way when not in use, to provide access to the drive casing (Figure 4).

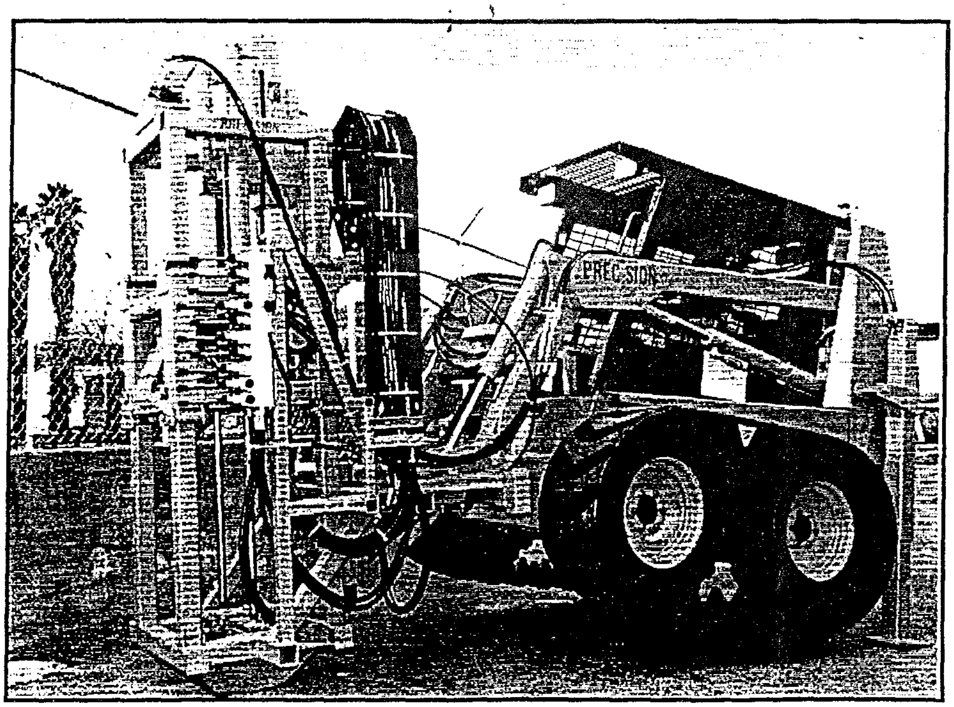


Figure 3. Precision's XD-1 Sampling Rig

The vibratory head is an important component of the driving mechanism and can greatly increase the rate of penetration and maximum sampling depth in certain types of soil. Vibratory techniques were initially used by the USGS for sampling unconsolidated off-shore sediments in the 1960's, and have been increasingly applied to environmental investigations. The vibrators used to advance the Enviro-Core system are twin hydraulically-operated, eccentric cam-type vibrators that clamp onto the outside of the Enviro-Core drive casing (Figure 4). Each vibrator spins at revolutions up to 4,500 revolutions per minute (rpm), creating a multi-directional vibration. When mounted opposed to one another, the opposing vibrations are canceled out, resulting in a uni-directional, up-and-down vibration (Barrow, 1994). In certain types of sediments (e.g., fine sands and silts), vibrating the Enviro-Core drive casing as the reactive weight is applied results in better sample recovery and a dramatic increase in the rate of penetration.

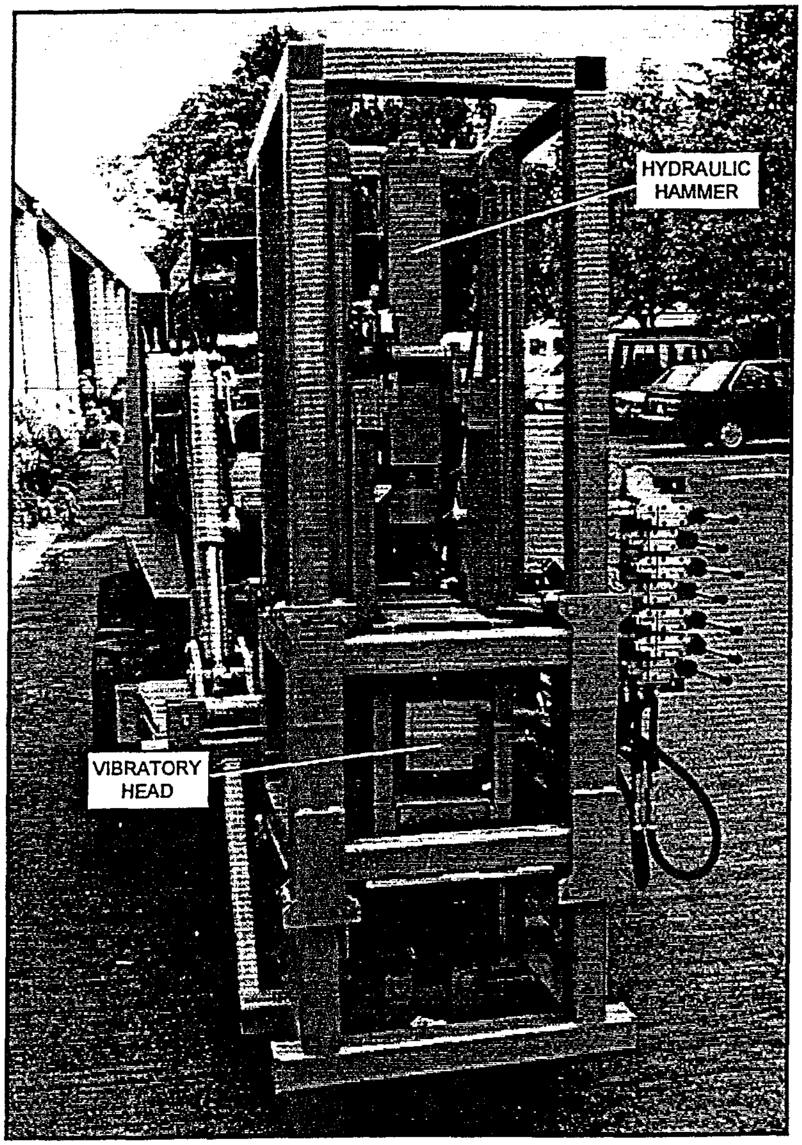


Figure 4. Components used to advance the Enviro-Core® System

The reactive weight (i.e., the weight of the sampling rig) is applied using hydraulic cylinders that press the hydraulic hammer and vibratory head down on the Enviro-Core drive casing. The rig operator can use either the hydraulic hammer or the vibrators in conjunction with the reactive weight, depending on the type of soil being penetrated. In stratified sediments, the rig operator continually alternates between pounding and vibrating the Enviro-Core system to gain the maximum sample recovery and rate of penetration.

Groundwater and Soil Gas Sampling with the Enviro-Core® System

The Enviro-Core system has several advantages over other DP tools for collecting soil gas and grab groundwater samples. First, unlike most other DP tools, the Enviro-Core is not a "blind" tool for collecting soil gas or groundwater samples. With a blind DP sampling tool, the probe is pushed ahead of the boring, into an interval of unknown lithology.

Problems associated with a blind DP tool are illustrated in the following hypothetical example. During a subsurface investigation, a geologist attempts to collect a grab groundwater sample using a hollow-stem auger rig and a conventional water sampling DP tool (e.g., Hydropunch, Geoprobe, BAT Enviroprobe, etc.) at a site with stratified sediments. The drill rig is used to collect soil cores and to push the water sampling tool. The water sampling tool is used to collect the grab groundwater sample (it does not provide any lithologic data). In this example, the boring penetrated a water-saturated sand bed from a depth of 17 to 20 feet. To collect a groundwater sample, the water sampling tool is pushed approximately 3 feet beyond the bottom of the boring (to a depth of 23 feet), and then pulled back slightly to open the tool. Unknown to the driller or site geologist, the sampling tool has been pushed "blindly" through the saturated sand, and into an underlying clay bed. Even though the clay may be saturated with water, the formation may not transmit measurable groundwater into the water sampling tool for days or weeks. Thus, the geologist is left wondering if the tool has clogged, malfunctioned, or has simply been pushed into a low-permeability stratum. For this reason, many investigators first define the stratigraphy in the area of interest with a drilling rig or CPT, and then advance an additional DP hole a few feet away to collect soil gas or grab groundwater samples.

The Enviro-Core system is not a "blind" tool because it collects soil cores (for lithologic control) as well as groundwater and soil gas samples. Grab groundwater samples are collected with the Enviro-Core system as follows. First, the field geologist or engineer identifies the depth from which she wants to collect a groundwater sample. She bases this on her observations of the soil cores that were just removed from the inner barrel. For example, she might notice moisture in pore spaces, root holes, or other voids, indicating that the sediments are saturated. Next, to confirm that the hole is actually "making water", she instructs the rig operator to pull back the drive casing a foot or two (the actual distance is based on the geologic conditions), allowing groundwater to flow into the borehole[1]. If cohesionless, collapsing sediments are anticipated, 1-inch-diameter slotted PVC pipe can be temporarily placed inside the drive casing before it is pulled back. The presence of groundwater in the drive casing or PVC pipe can be confirmed using an electronic well sounder lowered inside the drive casing or PVC pipe. Grab groundwater samples can then be quickly collected using a small-diameter bailer, check-valve tubing pump, or peristaltic pump. Thus, grab groundwater samples are more quickly collected than with "blind" DP tools, because they are collected from an interval where the lithology and corresponding water-transmitting characteristics of the sediments are known.

Soil gas samples are collected in a similar manner, except that steps are taken to minimize the volume of stagnant air that must be purged from the drive casing. After the desired soil gas sampling interval is identified (based on observations of the soil cores, as discussed above), a custom-made Viton® and stainless steel packer is quickly lowered to the bottom of the drive casing via a wireline. In addition to an inflation tube, this packer assembly also includes

[1] The inner barrel/packer assembly is removed from the drive casing during the time that grab groundwater and soil gas samples are collected.

1/4-inch-diameter polyethylene or Teflon® tubing used for collecting the soil gas samples (Figure-5). Once again, the drive casing is pulled back a short distance, exposing the walls of the boring. The packer is then inflated (from a nitrogen cylinder at the ground surface), forming a seal between the stagnant air in the drive casing and the soil gas in the target zone. Samples of the soil gas are collected by drawing a vacuum on the 1/4 inch sampling tubing in the manner performed with other soil gas sampling methods. The use of the inflatable packer to isolate the target zone greatly decreases the volume of gas that must be purged prior to collecting the soil gas sample.

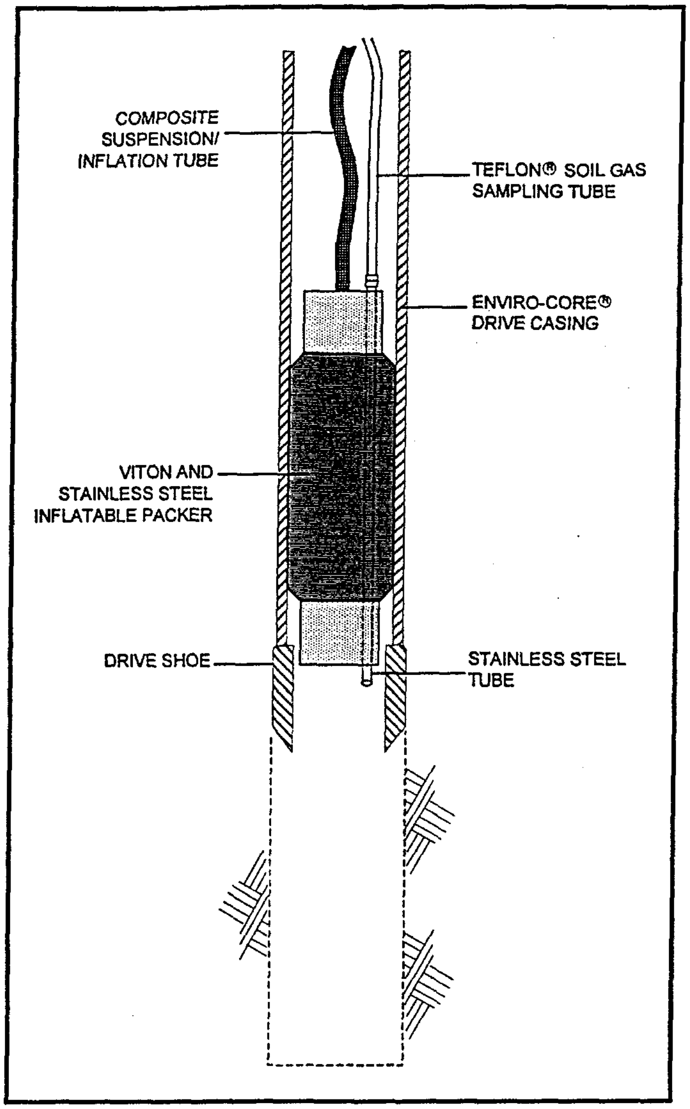


Figure 5. Wireline Soil Gas Sampling Tool

The Enviro-Core system holds another significant advantage over most other DP soil gas and groundwater sampling tools. The Enviro-Core system causes much less compaction of the sample zone than other DP tools. When a Hydropunch or Geoprobe is advanced into the soil, 100% of the soil is displaced. This creates a halo of compacted soil around the sampling tool. The compaction of the soil decreases the permeability of the soil surrounding the tool. This condition can greatly increase the time required to collect grab groundwater or soil gas samples in fine-grained sediments. With the Enviro-Core system, most of the soil is collected inside the inner barrel and removed from the boring. Since most of the soil is removed, there is much less soil displaced into the wall of the boring. Consequently, the formation of a low-permeability compacted zone is minimized, and soil gas and grab groundwater samples are collected more rapidly.

Other Applications and Uses of the Enviro-Core® System

Advancing small-diameter steel drive casing during the sampling process facilitates other characterization and remediation activities. As discussed above, the drive casing prevents the borehole from collapsing. Thus, small-diameter piezometers and monitoring points can be installed as the drive casing is withdrawn. Also, when the threads of the drive casing are wrapped with Teflon tape, the drive casing forms a water-tight seal against the formation. This facilitates depth-discrete hydraulic testing of the borehole as it is advanced. Some of the additional uses of the Enviro-Core drive casing are described in more detail below.

Piezometers and Monitoring Points

After the boring has been advanced to its total depth, small-diameter PVC piezometers and monitoring points can be installed. These piezometers are typically constructed of flush-threaded, 3/4-inch- or 1-inch-diameter, slotted PVC. After the last soil core has been collected and the inner barrel has been removed from the drive casing, sections of PVC are connected and lowered into the steel-cased borehole. After the PVC has been fully inserted, sand is poured into the annular space between the PVC well screen and drive casing. Next, the vibrators on the sampling rig are turned on, and the vibrating drive casing is slowly withdrawn. The action of the vibrators prevents the sand from "locking up" between the PVC and the drive casing. The sand falls out of the drive shoe, and forms a sand pack around the slotted PVC. Additional sand is added and the drive casing withdrawn further, until the sand fills the annulus to an elevation above the top of the slotted interval (the elevation of the top of the sand is measured with a small-diameter tamping rod or tag line). The installation is completed by adding an annular sealant (either small-diameter bentonite pellets, a high-solids bentonite slurry, or cement-bentonite slurry) as the remaining drive casing is removed.

Air Sparging and SVE Points

Small-diameter air sparging and SVE points can be installed in the manner described in the preceding section. However, an additional step is usually taken when installing air sparging points. Air sparging points are commonly installed many feet below the water table. In unconsolidated formations, the additional hydrostatic head can contribute to heaving sand conditions. This can make it difficult to insert the PVC fully, and can complicate the construction of the sparge point. To combat this, clean water can be added to the drive casing prior to withdrawing the inner barrel. The head of the added water counteracts the hydrostatic pressure of the groundwater, and minimizes the flow of water and unconsolidated sand into the drive casing. The PVC sections, sand pack, and annular sealant are then installed as described in the previous section.

Permeability Testing

In addition to physically supporting the borehole, the Enviro-Core drive casing forms a water-tight seal against the borehole. This allows in situ permeability tests to be performed as the boring is advanced. The general procedures for this are as follows. After the zone of interest has been cored, the drive casing is withdrawn, exposing the test zone[2]. The bottom of the test zone is the bottom of the borehole; the top is the drive shoe.

In fine-grained sediments where smearing can significantly decrease the secondary permeability created by root holes, fractures, etc., the test interval can be cleaned with a stiff nylon brush prior to performing the permeability tests.

[2] The distance that the drive casing is withdrawn (i.e., the test interval) depends on the thickness of the geologic unit being tested.

In unconsolidated sand where sloughing is expected upon withdrawal of the drive casing, a temporary well screen can be lowered to the bottom of the boring prior to pulling back the drive casing. The temporary well screen is constructed of short, interchangeable sections of stainless steel well screen attached to an inflatable packer (Figure 6). The length of the temporary well screen is selected to match the length of the test interval. When the drive casing is pulled back, the formation sloughs into the borehole, forming a natural sand pack around the temporary well screen. However, the temporary well screen maintains an open test interval. The pneumatic packer is then inflated to seal the annular space between the temporary well screen and the drive casing.

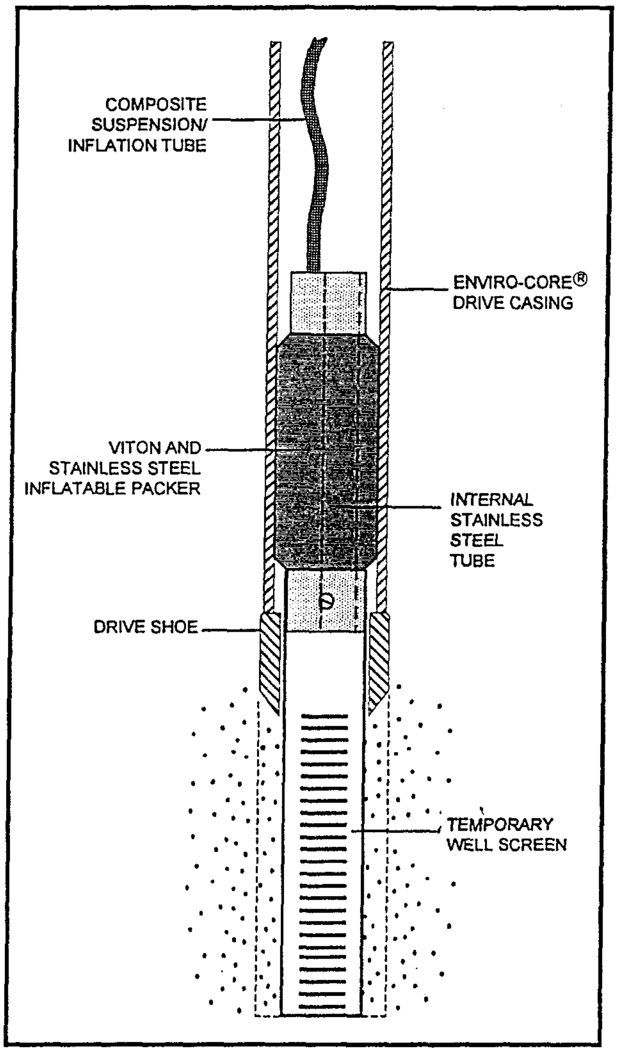


Figure 6. Wireline Temporary Well Screen

Rising or falling head tests (i.e., slug tests) can then be performed by adding or subtracting head inside of the drive casing. Plots of head versus time can be generated, and values of hydraulic conductivity can be calculated using standard analytical solutions such as Cooper et al. (1967) and Bouwer (1989). Constant head injection or extraction tests can also be performed following the procedures described in the US Department of the Interior's *Ground Water Manual.* In very low-permeability formations, pressure-decay tests can be performed following the methods of Bredehoeft & Papadopulos (1980). In fact, the Enviro-Core drive casing may be ideal for performing pressure decay tests since the expansion coefficient of the rigid steel drive casing, one of the sensitive parameters in the Bredehoeft & Papadopulos method (as explained in Neuzil, 1982), is expected to be small.

After the test is complete, the packer is deflated, and the temporary well screen is removed with a wireline. An empty inner sample barrel is again lowered to the bottom of the drive casing. The inner barrel is seated and affixed to the drive casing, and soil coring proceeds to the next interval where permeability data are desired. Another test would then be performed following the procedures discussed above. Thus, the Enviro-Core drive casing facilitates depth-discrete permeability testing. It is also possible to test the entire cored boring in this fashion.

Hydraulic and Pneumatic Fracturing

Another use of the Enviro-Core drive casing is for hydraulic or pneumatic fracturing of low-permeability sediments. Pneumatic and hydraulic fracturing can greatly increase the permeability of contaminated, low-permeability sediments. The increased permeability of the sediments results in more rapid remediation of soil and groundwater using SVE, air sparging, or in situ bioremediation (USEPA 1993a and 1993b).

The Enviro-Core drive casing may be an ideal way to rapidly fracture contaminated low-permeability sediments, especially in stratified environments. After a contaminated, fine-grained layer has been cored, the drive casing can be pulled back, exposing the contaminated zone. Because the drive casing effectively seals the rest of the borehole, compressed air or water can be pumped through the drive casing into the targeted zone. The rate of pumping is increased, raising the pressure in the isolated zone, until fractures develop and propagate in the impacted zone.

The pumping is then stopped, and an empty inner barrel is again lowered to the bottom of the drive casing prior to resuming soil coring. The boring is then advanced until the next fine-grained, contaminated stratum is encountered, and the fracturing process is repeated. Selective "enhancement" of the permeability of discrete fine-grained layers in this way could significantly increase the performance of many in situ remediation systems.

Geophysical Logging

While continuous soil coring is necessary to identify many features that affect contaminant migration and the feasibility of many remediation technologies, the lithologic data obtained from soil cores is subject to the interpretation of the field geologist or engineer who is logging the samples. A field geologist logging soil samples usually makes subjective decisions about the percentages of sand, silt, and clay contained in the soil. Even two experienced geologists describing the same soil sample will rarely describe the soil the same way. On large subsurface investigations where several geologists are working, the subjective nature of soil logging can hinder the correlation of subsurface geologic units.

Borehole geophysical logs provide a reproducible, *objective* measurement of the lithology of the soil (Keys, 1989). Thin, laterally-continuous beds that may be physically nondescript often display a unique geophysical signature that can be identified throughout the site on geophysical logs. For this reason, geophysical logging is a valuable component of many subsurface investigations.

The Enviro-Core system, in addition to collecting continuous soil cores, provides an open, cased boring in which geophysical logs can be run. Most types of geophysical logs that can be run in small-diameter, steel-cased wells (e.g., natural gamma, neutron, and gamma-gamma logs) can be run in the Enviro-Core drive casing before it is withdrawn from the boring.

Grouting

Borings which are not converted to piezometers, monitoring points, sparge points, etc., need to be sealed in accordance with state and local regulations. This is quickly accomplished with the Enviro-Core system. After the last soil core has been collected and the inner barrel has been removed, only the drive casing remains in the ground. Since the drive casing provides an open conduit to the bottom of the boring, it is an ideal tremie pipe. For grouting shallow borings, a bentonite or cement-bentonite slurry is poured into the drive casing from the ground surface as the casing is withdrawn. In deeper borings, the grout is pumped to the bottom of the boring through polyethylene tubing run inside of the drive casing. The grout slurry is pumped as the drive casing is pulled back.

Case Study

In April 1994, the Enviro-Core system was used to characterize a LUFT site in Redwood City, California. The site, located approximately 30 miles south of San Francisco, is underlain by sand, silt, and clay sediments that were deposited in lacustrine and fluvial environments. Groundwater occurs at a depth of approximately 8 feet. Leakage from an underground fuel storage tank resulted in significant impacts to soil and groundwater beneath the site.

The Enviro-Core system was used to continuously core 17 borings to an average depth of 18 feet, with sample recovery greater than 90 percent. The soil cores were logged by a geologist who directed the field investigation. Grab groundwater samples were collected from seven of the borings, and eight of the borings were converted to temporary piezometers. Soil and groundwater samples were analyzed on site using a mobile analytical laboratory. The mobile lab was an important component of the investigation because it provided real-time data that the field geologist used to select the locations of subsequent borings. After one week, water levels in the piezometers had equilibrated.

Lithologic data collected with the Enviro-Core system resulted in a clear definition of several important hydrogeologic units. Water-saturated artificial fill was identified beneath several parts of the site, and a coarse-grained sandy channel was identified beneath the western portion of the site (Figures 7 and 8). Chemical analysis of soil and groundwater samples completely defined the nature and extent of soil and groundwater contamination. Finally, stabilized piezometric data from the small-diameter piezometers provided important information about the movement of groundwater beneath the site.

Use of the Enviro-Core resulted in the complete characterization of the site geology, hydrogeology, and nature and extent of contamination. Moreover, the entire field program, including the continuous soil coring, chemical analysis of soil and groundwater samples using the mobile lab, and installation of eight small-diameter piezometers, was completed in just two days.

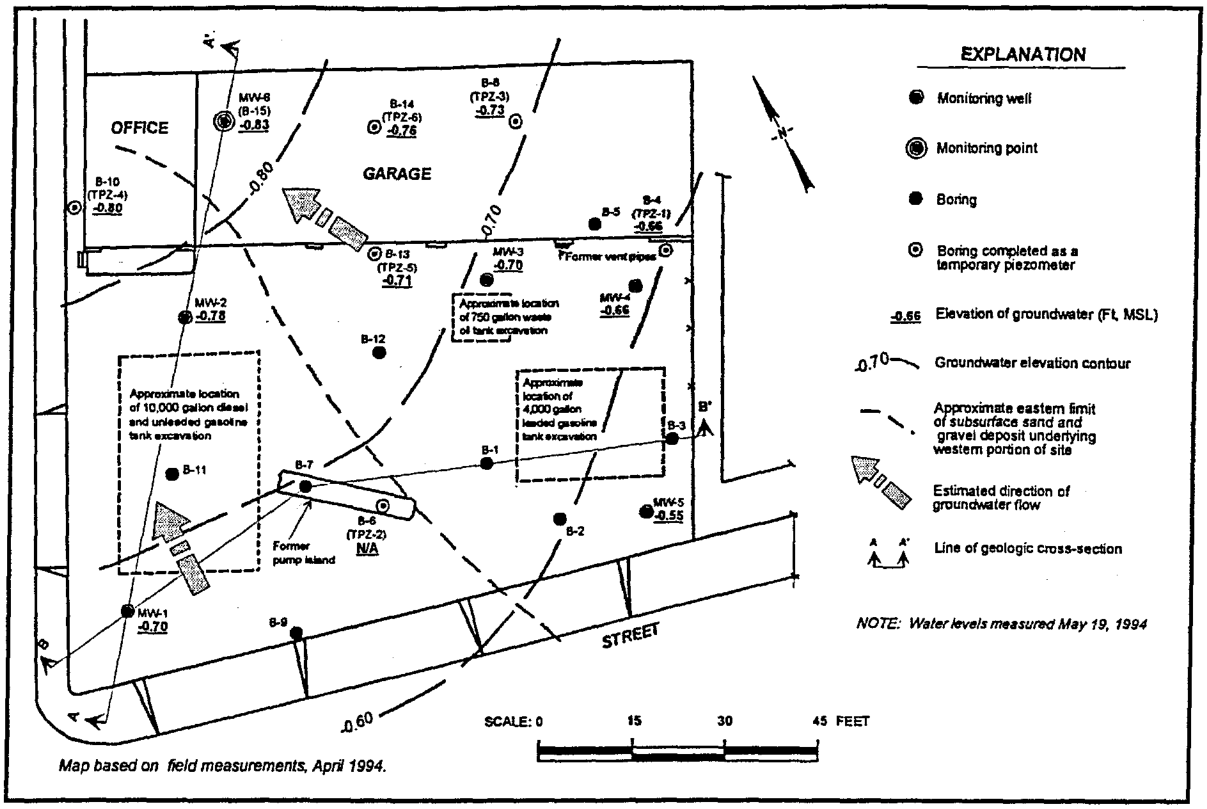


Figure 7. Site Plan and Groundwater Contour Map, Redwood City LUFT Site

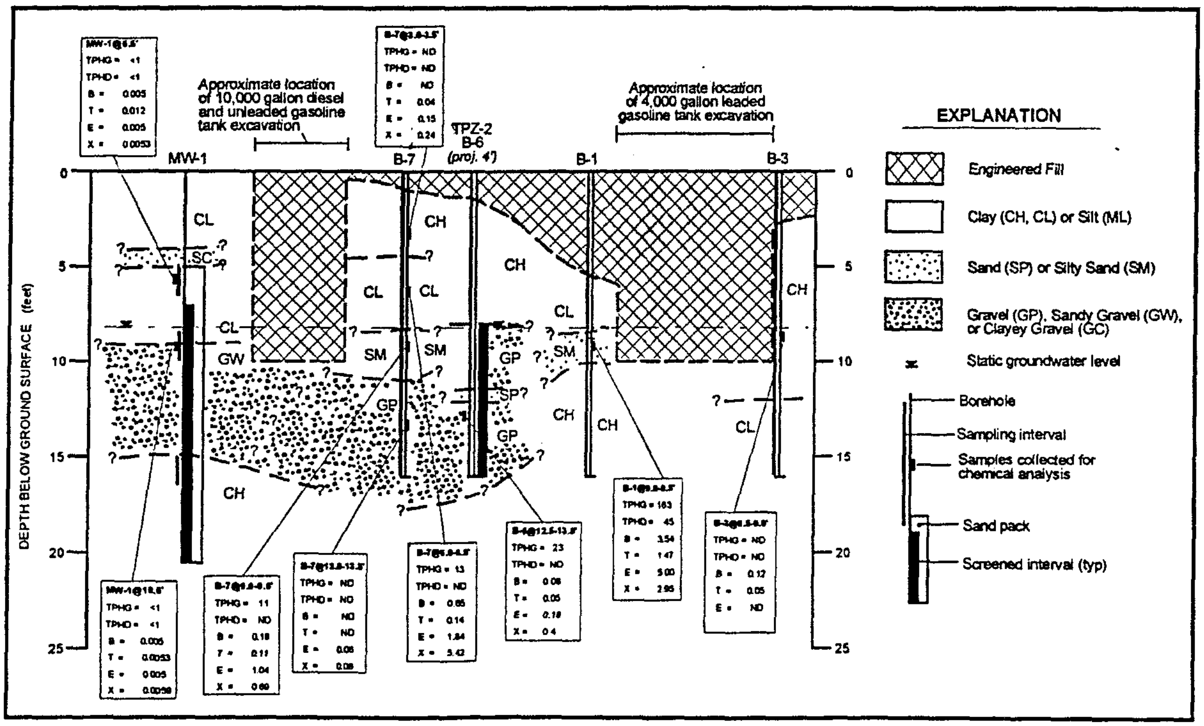


Figure 8. Cross Section B-B', Redwood City LUFT Site

Current Limitations of the Enviro-Core® System

Like all DP tools, the Enviro-Core works best in relatively unconsolidated sediments, although the system has worked well at sites underlain by weathered bedrock. Also, the Enviro-Core system does not work well at sites where there are thick cobble and coarse gravel layers.

Currently, the maximum depth that can consistently be reached with the Enviro-Core system in the San Francisco Bay Area is approximately 45 feet. As with other DP tools, the maximum sampling depth and rate of penetration are highly dependent on subsurface conditions. Also, the maximum reactive weight applied to the Enviro-Core sampling system to date is 3,500 pounds. Application of greater reactive weight is expected to significantly increase the maximum sampling depth.

Also, as with most other tools for subsurface investigation, unconsolidated, heaving sands create difficult sampling conditions for the Enviro-Core system. In particular, sand flowing up into the drive casing can make it impossible to seat the inner barrel correctly. Problems with loose, heaving sands are exacerbated when borings are advanced great distances below the water table. Problems with heaving sands can be alleviated somewhat by maintaining a head of water in the drive casing greater than the hydrostatic pressure in the formation.

Summary and Conclusions

The Enviro-Core is a valuable new DP tool for quickly collecting continuous soil cores, soil gas samples, and grab groundwater samples. An important part of the Enviro-Core system is the small-diameter drive casing, which is not removed until the boring has been advanced to its final depth. The use of small-diameter drive casing facilitates in situ hydraulic testing, geophysical logging, and installation of small-diameter piezometers, monitoring points, air sparging points, and SVE points.

The future may hold promising new applications for the Enviro-Core system, including in situ pneumatic or hydraulic fracturing, or other characterization or remediation activities that could utilize small-diameter, steel-cased borings. The Enviro-Core system is not ideal for every site, but it is a welcome addition to the growing list of DP tools for site characterization and remediation.

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Biographical Sketch

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Appendix B

The Waterloo Drive-Point Profiler, Detailed Profiling of VOC Plumes in Groundwater

The Waterloo Drive-Point Profiler. Detailed profiling of VOC plumes in groundwater aquifers

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ABSTRACT: The Waterloo Drive-Point Profiler, developed for use in sand and gravel aquifers, consists of a small stainless steel tip attached to single or dual stainless steel tubes, for suction and nitrogen purge sampling respectively, that rise inside black steel pipe. Samples are taken at narrow intervals to obtain detailed vertical profiles. The development of the profiler has been based on several field tests in a shallow homogeneous sand aquifer at a research site used for controlled releases of chlorinated solvents, and in a deeper heterogeneous sand aquifer at an industrial dry cleaning site. The profiler provides a detail in resolution of the spatial concentration distribution, that can provide new insight into the internal pattern of contaminant plumes. This insight is important for the understanding of contaminant migration and for optimized groundwater remediation.

1 INTRODUCTION

Detailed profiling of contaminant plumes in groundwater is important for the understanding of contaminant transport and for optimized remediation of contaminated groundwater. Sufficient detail generally cannot be accomplished using conventional monitoring wells, because of limitations due to scale of sampling and cost.

Many contaminant plumes, in particular those emanating from free liquid phase sources purged on the watertable, e.g. gasoline, or existing as residual and pools in the aquifer, e.g. chlorinated solvents, exhibit very large vertical concentration gradients. Chlorinated solvents and gasoline constituents are frequently-encountered groundwater contaminants, with a volatile and sorptive character.

Representative detailed vertical profiles of such plumes rises special requirements to techniques and materials, as is demonstrated by the results of the field tests presented in this paper.

2 DESIGN AND CONSTRUCTION

The profiler has been developed from the Waterloo Drive-Point Piezometer (Ingleton and Cherry, 1993).

2.1 *Drive point piezometers*

Conventional drive-point piezometers consist of a metal or plastic tip or screen attached to pipe that is driven into the ground using force or vibration at surface. Drive-point piezometers have the advantage over conventional wells that no soil cuttings are brought to the surface, whereby health risks and costs associated with the handling and disposal of contaminated soil is avoided. The relatively small screen and riser pipe diameter of drive-point piezometers combined with the lack of sand or gravel pack and the limited disturbance of the aquifer material limits the volume of water that has to be purged prior to sampling for water quality analysis. Most commercially available groundwater probes designed for sampling and profiling of contaminant plumes in groundwater resemble the Waterloo Drive-Point Piezometer.

The Waterloo Drive-Point Piezometer has a tip consisting of a 20 cm to 50 cm long screened section and drive-point, entirely made of stainless steel. The tip is attached to tubing rising to surface inside black steel pipe. The selection of tubing is generally made from polyethylene, polypropylene or teflon, however, stainless steel tubing can also be used. The Waterloo Drive-Point Piezometer therefore is well suited for sampling for nearly all types of polyethylene or stainless steel tube and the peristaltic pump. The samples were analyzed for TCE and PCE content by pentane micro-extraction followed by gas chromatography with electron capture detection for this and the subsequent tests. The same analytical technique as was generally used for the monitoring of samples from the Borden sites (Rivett et al., 1993 and Broholm, 1994). The piezometer were placed between two multilevels (ML2 and ML14) in line with the centre of the plume close to the source. The distance from ML2 was 25 cm to ss-s, 50 cm to ds-np, 80 cm to pe-s and 400 cm to ML14. Samples were taken at 20 cm intervals, corresponding to the spacing of points on the nearest multilevel device. Water samples were also obtained from the multilevels (ML2 and ML14) for comparison of the results.

The concentrations of PCE and TCE in the groundwater decreases from ML2 towards ML14, therefore concentrations at a given elevation would be expected to decrease in the order: ML2, ss-s, ds-np, pe-s to ML14. Below the plume, however, low concentrations are found in the multilevel water samples, as a result of diffusion of contaminants through the multilevel teflon tubing passing through the plume (Rivett, 1993). This effect has also been observed at other field sites (Barker et al. 1987). For the water samples obtained with the stainless steel piezometer, hence, lower concentrations would be expected for the deepest sampling points. For tubing materials, such as polyethylene, PVC and teflon, sorption of organic contaminants is known to occur (Gillham et al. 1983, Barker et al. 1987). Though the depletion of organic concentrations in the aqueous phase is insignificant, when sufficient purge volumes are used, the subsequent desorption may well cause carry-over to less contaminated water samples. This effect would be expected for the piezometer with polyethylene tubing for the deeper samples.

The results of the sample analysis for TCE and PCE are illustrated in Figure 1, for the three piezometers.

The overall position of the plume was correctly mapped with all three piezometers.

For the ds-np piezometer, due to the shallow depth below the watertable and the small volume of water in the tubing above the check-valve, even sampling was very time consuming and the purge volumes aimed for were far from obtained. The samples were therefore being diluted with water from above the plume, resulting in TCE and PCE concentrations of the samples almost two orders of magnitude lower than the expected groundwater concentrations at the peak of the plume. Nitrogen pressure applied during the driving of the piezometer helped to prevent fines from blocking the check-valve and application of suction during the initial purging was found to facilitate the entry of water.

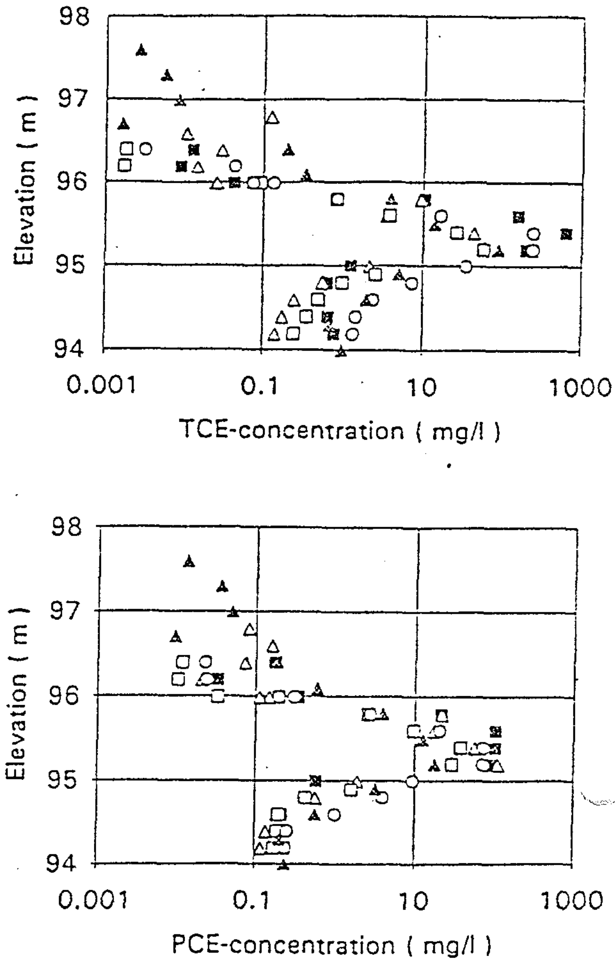

Figure 1: TCE (a) and PCE (b) concentration profiles from the Emplaced Source Site (■ ML2, + ss-s, ◊ ds-np, ○ pe-s. ▲ ML14)

The ss-s piezometer performed well in the field. The purge volumes aimed for were obtained with an average purge and sample time for a point of app. 20 min. A sample was even obtained slightly above the watertable in the capillary fringe. Backsuction of water from the sample vial resulting in headspace occurred initially, but was soon solved with a hose and clamp system.

Lots of air was observed to purge through the samples while sampling within the upper 1 m below the water table with the pe-s piezometer, possibly due to the large diameter of the tubing combined with suction sampling. Purging was very slow in s upper section. Below app. 1 m it performed extremely well and more than the volumes aimed for were obtained in less than 10 min.

The results strongly indicate, that the purge inorganic and organic groundwater contaminants. Sampling can be performed by suction or positive displacement with air or gas.

Water can not be lifted more than 7 or 8 meters by suction. Suction sampling is therefore limited to aquifers with a potentiometric head higher than app. 7 m below ground surface (m b.g.s.). Sampling by suction may cause a negative sample bias due to volatilisation as a result of the exposure of the sample to negative pressure. Positive displacement methods are less likely to cause volatilisation of contaminants, but contact with air or carrier gas (e.g. nitrogen) may cause partitioning of contaminants to the air or gas (Gillham et al.1983). The negative bias of suction by a peristaltic pump and of an air lift system was found to be between 2 and 12 % (Baerg et al. 1992) and less than 20 % (Barker et al. 1987), respectively. These biases are not considered to be of major significance for contaminant profiling.

Based on the field tests presented in this paper the drive-point piezometer has been subject to several modifications to derive at the design of the profiler.

2.2 *The Waterloo Drive-Point Profiler*

The Waterloo Drive-Point Profiler consist of a small stainless steel tip attached to single or dual stainless steel tubing that rises inside black steel pipe.

The tip consist of a sharpened stainless steel conical drive-point fitted with a NPT female thread to accept a stainless steel male barb tubing connecter. Two to six 6 mm (1/4") diameter circular stainless steel or sintered stainless steel screens are inserted in threaded drilled holes in the upper end of the drive-point. The screens are easily exchanged to suit the specific aquifer material. Single 3 mm (1/8") diameter or dual 6 mm (1/4") diameter stainless steel tubing is attached to the tip. The dual tube has a check-valve at the connection to the tip. The tubing is extended to surface with 1.5 m (5 feet) lengths of stainless steel tubes connected with stainless steel swage-lock fittings. After the machining of the components is completed, residual oil and cuttings are removed by a laboratory organic washing procedure. Standard 12.5 mm (only for single tubing) or 25 mm (1/2" or 1") steel water pipe in 1.5 m (5 feet) lengths is threaded and used as driving and riser casing connected with wrought iron threaded couplings.

The upper end of the single stainless steel tubing is equipped with a stainless steel switch-valve and a pressure gage, and connected to a stainless steel sampling head to which the sample vial is attached. The sampling head is connected to a peristaltic pump for suction sampling. The switch-valve is used to prevent back-suction from the sample vial when the pump is turned off, and allows for nitrogen pressure to be applied if the screens are blocked.

One of the dual stainless steel tubes is equipped with a switch-valve for connection of nitrogen pressure for nitrogen purge sampling. The sample is then obtained from the other tube.

3 FIELD TESTS AND RESULTS

3.1 *Emplaced Source Site test*

At the Emplaced Source Site, one of the WCGR research sites at C.F.B. Borden in Ontario, Canada, a source consisting of sand mixed with immiscible phase perchloroethylene (PCE), trichloroethylene (TCE) and chloroform (TCM) was placed in the natural shallow homogeneous aquifer in 1989, allowing a dissolved phase plume to develop (Rivett et al., 1993). The plume is monitored in a network of multilevels placed downstream of the source.

The initial test was carried out at this site. The original Waterloo Drive-Point Piezometer, with a 20 cm long screened tip and polyethylene tubing (12.5 mm (1/2") diameter) for suction sampling (pe-s), and two modifications of this were tested:

- one with a single stainless steel tube (3 mm (1/8") diameter) directly attached to the tip for suction sampling (ss-s) and
- one with dual stainless steel tubes attached directly to the tip for nitrogen purge sampling (ds-s).

For conventional wells purge volumes of 3 to 5 times the volume of water in the well and sandpack has based on stabilization of water chemistry been found to be sufficient (Gibb et al., 1981, for example). Gillham et all. (1985) found, that provided a flushing procedure is used that removes all the water initially in the well, then removal of 2 to 3 well volumes is sufficient to flush a well. For bundle multilevel piezometers Barker et al. (1987) found that 3 piezometer volumes was adequate in a field test for chlorinated solvents in a landfill leachate plume.

Purge volumes of 165 ml to 250 ml, corresponding to 3 times the volume of water in the tip and tubing, were therefore aimed at in this initial test.

Water samples were taken in 15 ml hypovials with teflon-silica septa and aluminium crimp-caps. For suction sampling the vials were equipped with a stainless steel sampling head placed between the volumes aimed for and obtained for the ss-s and pe-s piezometers, were not sufficient. All the water in the relatively large piezometer tip is apparently not initially removed. Larger purge volumes relative to tip and tubing volume, such as obtained for the pe-s piezometer at depths > 1 m, therefore has to be used.

A tailing effect with concentrations an order of magnitude too high was observed below the peak of the plume for the pe-s piezometer as expected as a result of sorption and subsequent desorption. For detailed profiling of plumes, especially in more heterogeneous aquifers, the use of sorping tubing materials, such as polyethylene, PVC and teflon, should be avoided.

3.2 *The Angus Site*

The drinking water from some private wells in Angus, Ontario, was analyzed in a survey by the Ontario Ministry of Environment and found contaminated with PCE. A nearby industrial dry cleaning facility is suspected to be the source of the contamination.

In a combined effort to locate the PCE-plume and test the profiling devices, they were used at the Angus site. Field tests with the piezometer and profiler were carried out in November - December 1992 and May 1993.

Soilcores, taken at the site, revealed a much more heterogeneous aquifer than the Borden aquifer. The aquifer was found to be divided in a shallow and a deeper section by an 80 cm thick silt layer and a 10 cm thick peat layer at 4.8 to 5.9 m b.g.s. The water table was located app. 2.5 m b.g.s. The aquifer sections consisted primarily of sands varying from fine, silty sand to coarse, gravelly sand. In the deeper section permeabilities varied between 2 and 31 cm/s. The plume is located in the deeper section of the aquifer.

The first test was carried out in the upper section of the aquifer with the drive point piezometer with single stainless steel tubing (ss-s), which had performed well at the emplaced source site. The purge volumes of 600 ml chosen were very time consuming to obtain, especially as some of the fines from the more heterogeneous aquifer materials would block the screens or the inlet to the tube. After passing through the silt layer the screen was totally blocked and further sampling was given up.

It was then decided to design a smaller tip with a minimal internal volume (< 10 ml) and smaller screened area for the ss-s as well as the ds-np device. The resulting design, here termed the Waterloo Drive-Point Profiler, was used for all subsequent profiling.

To examine the possible location of the plume in the deeper section of the aquifer access was ma[illegible] through a cored hole in the silt and peat layer and a few samples were taken. The screen used was a very fine mesh and got blocked quite easily. Running the pump in reverse a few times, thereby flushing in-situ water back and forth through the screens, however, worked well to develop them. In a later field test (section 3.3) the use of coarser screens for the profiler, when used in sands with many fines, was found to enable fines to be flushed out, whereby a small sandpack is developed in situ. Downward transfer of water with the profiler was prevented by running the pump in reverse after a sample was taken, thereby pushing the water back out in-situ, and while driving it. At the next point one tip volume was purged before the screens were developed by backflushing. Since the water volume in the profiler is thereby reduced to the volume below the screens, the 100 ml total purge volume chosen corresponds to more than 10 times the internal volume of water independently of the depth below the water table. The results of the sample analysis are illustrated in Figure 2 (1992).

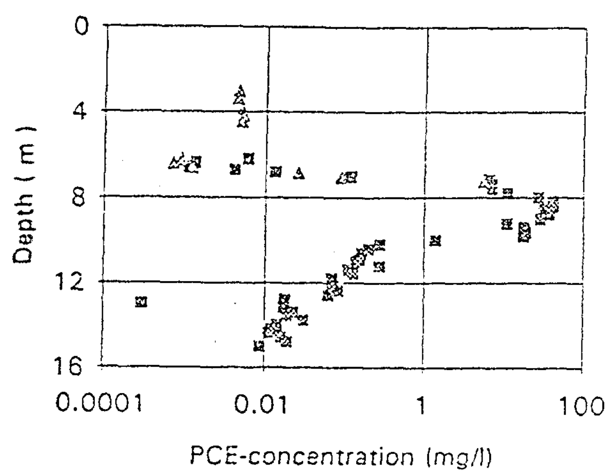

Figure 2: PCE concentration profile from the Angus Site (▲ 1992, ▪ 1993).

During winter the profiling devices described in section 2.2 were designed and constructed. A more detailed description of the profilers will be given by Ingleton et al. (1993).

In May 1993 the ss-s profiler was driven thro[illegible] the silt and peat layer app. 20 cm from the location of the previous year and a full profile through the deeper section of the aquifer was sampled. The full PCE profile is illustrated in figure 2 (1993).

Other smaller discrepancies may likewise be related to geologic heterogeneity.

In horizontally stratified aquifer sections with very fine beds smaller vertical sampling intervals may be required to obtain optimal resolution in the spatial concentration distribution. The small screens of the profiler and the small purge volume required combined with the preferentially horizontal flow in horizontally stratified media is believed to enable profiling with a vertical spacing between sampling points of a few (2-3) cm.

4 CONCLUSIONS

The field tests presented in this paper demonstrates, that representative detailed profiling of volatile organic contaminant plumes exhibiting large vertical concentration gradients require special techniques and materials.

The Waterloo Drive-point Profiler fill these requirements. Profiling with the single stainless steel tube profiler for suction sampling has proven very effective in heterogeneous aquifers with permeabilities varying between 0.002 and 0.031 cm/s. A profile to a depth of 14 m with 48 sampling points was obtained in app. 12 hours, which corresponds to the time required for installation and sampling of a single well of the same depth. The dual tube profiler for nitrogen purge sampling has not yet been sufficiently tested.

Detailed profiling of contaminant plumes is important for the understanding of contaminant transport and for optimized groundwater remediation. The Waterloo Drive-point profiler provides a detail in resolution of the spatial concentration distribution, that can provide new insight into the internal pattern of contaminant plumes.

5 ACKNOWLEDGEMENTS

This work was supported by the University Consortium Solvents-in-Groundwater Research Program which is sponsored by Boeing, Ciba-Geigy, Eastman Kodak, General Electric, Laidlaw Environmental Services, the Ontario Research Incentive Fund and the Natural Sciences and Engineering Research Council of Canada. The Angus site was provided by the Ministry of Environment, Ontario, Canada. The provision of their experimental sites for use for the field tests and help locating the plumes by Michael Rivet and Kim Broholm, Waterloo Centre for Groundwater Research, is greatly appreciated by the authors. The field and laboratory work by Seth Petkin, Scott Sale, David Baerg, Jeff Murphy, and Kim Broholm, Waterloo Centre for Groundwater Research, is also greatly appreciated.

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The screens got blocked, when the profiler was driven through the silt layer, as expected. Nitrogen pressure was applied, whereby the silt was blown of the screens and enough water allowed to enter, to flush some of the fines out with in-situ water. This was repeated a few times until the water pumped up was free of fines. The profiler was driven a little deeper to avoid nitrogen gas from purging through the sample.

The regular development of screens, purging and sampling, and driving of the profiler could then be resumed.

Purge and sample time for each point was 5 to 10 min. for aquifer sections of sands with permeabilities larger than 0.01 cm/s. In fine silty sands with permeabilities between 0.002 and 0.01 cm/s purge and sample times where 10 to 30 min. The full profile, including set-up, driving to and sampling at 48 points between 6 and 14 m b.g.s., pulling the rods and packing up, was performed in 1 1/2 day (app. 12 hours).

The profile obtained provides a detail in resolution of the PCE concentration distribution, that is much higher than can be obtained by nests of monitoring wells. The detail in resolution obtained with the spacing here chosen can provide a better understanding of plume migration, and provide a far better basis for efficient plume remediation than normally available.

3.3 *The Released Source Site test*

A heterogeneously distributed solvent source was established by the controlled release of 5 l of a solvent mixture consisting of PCE, TCE and TCM into the shallow aquifer at C.F.B. Borden in 1992. The dissolution of the source was studied in a controlled flow field by downstream monitoring in a cross-section of nests of stainless steel probes with 10 cm vertical spacing between points (Broholm, 1994).

The profiler with single stainless steel tubing was tested at the Released Source Site on April 29th, 1993. The profiling was performed app. 30 cm upstream of the centre of the sampling nest, where the highest concentration gradient in the groundwater was found. Samples were taken at 10 cm intervals corresponding to the vertical spacing of sampling points in the sampling nest. The two top points sampled were in the capillary zone above the water table. Air purged through these samples, and no purge volume and a 50 ml purge volume was obtained for the top and second point, respectively. For all deeper points a purge volume of 80 ml was used. In the top 1/3 of the section sampled, very fine mesh screens were used. As the aquifer material got very fine with depth and kept blocking the screens, they were exchanged with coarser screens. At first nitrogen pressure was applied while the profiler was driven down, but running the pump in reverse proved to be as efficient and eliminated the problem of nitrogen gas purging through the water.

The samples were analyzed at the same time and by the same analytical technique as the set of samples from the sampling nest obtained the same day (Broholm, 1994).

The solvent concentration profiles resulting from samples obtained with the profiler are compared to those from the sampling nest in Figure 3. Solvent concentrations are here presented on a linear rather than log scale to enhance the small differences in concentration at the peak of the plume.

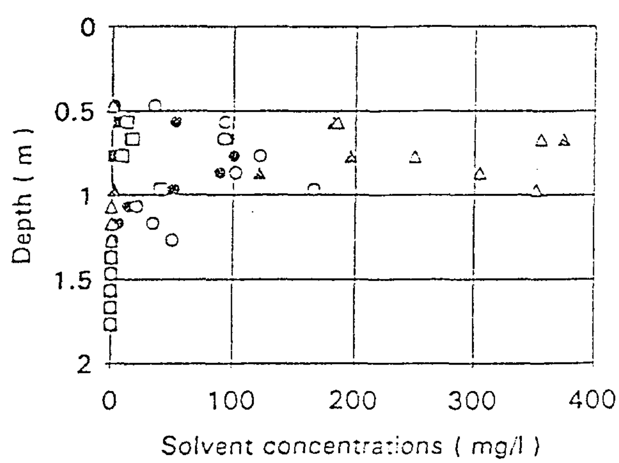

Figure 3: TCM (■ □), TCE (▲ △) and PCE (● ○) concentration profiles from the Released Source Site (■ profiler, □ reference).

The concentrations of the samples obtained with the profiler compare remarkably well with the concentration of the samples from the site sampling nest. The results for the second sampling point indicate that a purge volume of 50 ml is sufficient.

The largest discrepancy between concentrations is observed at 0.97 m b.g.s. The excavation of the source revealed a thin (4-8 cm) lens of fine-medium sand in an otherwise very fine section of sand situated just above the profiler sampling point and dipping slightly towards the sampling nest. The corresponding point of the sampling nest, hence, was situated in the described lens. The discrepancy is therefore believed to be a result of the small (<10 cm) scale geologic heterogeneity, with the lens providing a pathway for the contaminant plume.

Appendix C

Site Health and Safety Plan

N00236.001467
ALAMEDA POINT
SSIC NO. 5090.3

APPENDIX C - SITE HEALTH AND SAFETY PLAN

PAGE 2

WORK PLAN FOR HYDROGEOLOGIC INVESTIGATION, SITE 1

EXTENSIVE RESEARCH WAS PERFORMED BY NAVFAC SOUTHWEST TO LOCATE THIS PAGE. THIS PAGE HAS BEEN INSERTED AS A PLACEHOLDER AND WILL BE REPLACED SHOULD THE MISSING ITEM BE LOCATED.

QUESTIONS MAY BE DIRECTED TO:

DIANE C. SILVA
RECORDS MANAGEMENT SPECIALIST
NAVAL FACILITIES ENGINEERING COMMAND SOUTHWEST
1220 PACIFIC HIGHWAY
SAN DIEGO, CA 92132

TELEPHONE: (619) 532-3676

photo-ionization detector (PID). If vapors are detected at 10 ppm or greater above background measurements in the workers' breathing space, action will be taken to mitigate any potential exposure. If potential exposure to workers persists, the need for upgrade to level C respiratory protection, consisting of at least half-mask respirators with organic vapor cartridges, will be analyzed.

RADIOLOGICAL HAZARDS

This section on radiological hazards has been prepared based in-large-part on information presented in PRC Environmental Management's site-specific radiological health and safety plan, provided to EFW by the Department of the Navy, Environmental Program.

Low-level radiological wastes were deposited in the area from 1943 to 1956. These materials primarily consist of radium-coated dials from instruments. A recent surficial radiation survey indicated some areas of low-level impact in the proposed work area. Radium is a carcinogen when taken into the body. Radium is a "bone-seeker", replacing calcium in metabolic processes. The primary route of exposure for radionuclides is by inhalation of impacted dust particle. Care will be taken, therefore, not to raise excessive dust from surface activities.

Personnel and the work area in general will be monitored at least hourly using a hand-held radionuclide meter (Geiger-Mueller meter or equivalent). Radiation readings in excess of five times background (assumed to be 0.02 milliroentgrens per hour [mr/hr]) will be cause to upgrade to level C respiratory protection using HEPA filters with a half mask respirator. Readings in excess of 2mr/hr will be cause to cease work and evacuate the area, pending further evaluation by a certified health physicist.

Prior to lunch breaks, and before leaving the site, workers shall wash hands and face. Workers will be screened for radionuclides upon leaving the work area. Any clothing, personal belongings, or equipment must be verified clean before leaving the work area.

Personal dosimetry may be required for some or all personnel. If any detector exceeds background by a factor of 10, potential exposure in the work area will be re-evaluated.

SITE CONTROL MEASURES

The site is closed to the general public and the area around the drill rig will be kept clear of non-work related traffic.

DECONTAMINATION PROCEDURES

All equipment that comes into contact with contaminated soil or groundwater will be appropriately decontaminated prior to leaving the site.

MEDICAL MONITORING AND TRAINING

All project personnel shall have completed medical monitoring and training which meets the requirements of 29 CFR 1910.120, prior to working at the site. No additional medical monitoring is required for this work. All site personnel shall review this health and safety plan prior to starting work at the site. Site safety meetings will be held at the work site each morning before work begins to update any changes to this health and safety plan.

EMERGENCY PROCEDURES

Possible emergency situations are generally considered to include worker injuries, contact with utilities, and acute exposure to contaminants. Worker injuries will be treated on site with first aid, or by 911 emergency personnel if the injury requires immediate medical attention. A fire extinguisher, mobile phone, first aid kit, and rinse water will be maintained in the active work area.

EMERGENCY PHONE NUMBERS

Fire, police and ambulance 911

Einarson, Fowler & Watson 415/843-3828

Precision Sampling... .... 415/456-9875

This Site Health and Safety Plan has been prepared based on available information. Revisions or addenda to this plan should be made as more information is gathered. These revisions/addenda should be incorporated into this plan, noted below, and made available to all involved personnel.

Gregory J. Smith

Gregory J. Smith, EFW Health and Safety Officer

Revisions/Addenda (0) 7/16/96 (1) _______ (2) _______ (3)________

THE UNDERSIGNED HAVE READ AND UNDERSTOOD THE ABOVE SITE SAFETY PLAN.

NAME	COMPANY	DATE